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Measuring the Spatial Distribution of Ripples Using a REMUS AUV

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LONG-TERM GOALS

The long term goal of this work is to increase our understanding of bedform geometry and processes associated with bedforms on the continental shelf. To do this we have been developing novel measurement techniques, conducting observations of both the spatial and temporal variability of ripples and developing a variety of model approaches.

OBJECTIVES

Models to predict seafloor ripples generated by wave and current forcing generally have been based on the assumption that the ripples are in equilibrium with hydrodynamic forcing when the stress at the seafloor is sufficient to move sediment. Equilibrium models typically predict relict ripples (ripples left behind after storms) that have shorter wavelengths than the observations by a factor of around two. In this work, a model that allows a temporal delay between ripple adjustment and hydrodynamic forcing is investigated. Thus, the primary objectives of this work are:

- Measure the temporal and spatial variability of ripple geometry in wave dominated shelf environments using both stationary tripod mounted sonar systems and AUV sidescan systems.

- Develop models to predict ripple geometry as function of hydrodynamic forcing and seafloor sediment characteristics. In particular, the models focus on increased skill in predicting ripples remaining after storms.

APPROACH

Observations: Previously collected time series of ripple geometry in 12 m water depth and medium to coarse grain size sand at LEO-15 (southern New Jersey) and MVCO (south of Martha's Vineyard, MA) were utilized in this study. All of the data sets contain wavelength measurements estimated from rotary sidescan sonar imagery (Figure 1), and one of the MVCO data sets contains ripple height measurements from a 2-axis rotary pencil beam system. This data can be used to calculate spectra of seafloor ripple elevation variance in the wavenumber band from 0.5 to 10 cycles/m. Due to the medium to coarse sand size present at both sites, the data typically show that ripples were orbital scale ripples with wavelengths that scale with the orbital diameter of the surface gravity waves during moderate energy conditions. The data also show that large wavelength (0.7 to 1.2 m) relict ripples are present after wave events (Figure 2b). During the beginning of the next wave event there is often a

period where bimodal spectra exist as short wavelength ripples from the new storm are present in conjunction with long wavelength ripple left by the previous storm (Figure 2a).

More recently collected data on the spatial variability of ripples collected as part of the ONR RipplesDRI/SAX04 experiment conducted on the Florida gulf coast south of Fort Walton Beach was also ultized. This data was collected with a REMUS AUV which allowed high resolution (3 to 4 cm) sidescan imagery to be collected from 5 m to 50 m water depths (Figure 1). The measurements were conducted in September of 2004, two weeks after the passage of hurricane Ivan 150 km to the west of the study area. The post Ivan data show relict ripple wavelengths increasing from 0.5 m wavelength in 20 m water depth to 0.9 m wavelength in 50 m water depth despite the fact that wave orbital diameters generally increase with decreasing water depth.

RESULTS

Time dependent model: A time dependent ripple model was developed by using the orbital scaling relation of wavelength equal to 0.75 orbital diameter (Traykovski, 1999), combined with a maximum ripple wavelength based on threshold for full suspension. The unique characteristic of this model was that it included a temporal delay between ripple adjustment and hydrodynamic forcing. The temporal delay is determined by the ratio of the ripple cross-sectional area to the bedload transport rate. (e.g. large ripples with weak forcing adjust slowly and small ripples with strong forcing adjust quickly.) For small ripples that are typically present in fine sand, the non-equilibrium model predictions are similar to the previous equilibrium models, but in coarse sand substantial differences emerge. Models that assume ripples are in equilibrium with hydrodynamic forcing until the stress becomes subcritical typically predict much shorter relict ripple wavelength, while including the adjustment delay allows the non-equilibrium model to predict relict ripple wavelengths consistent with the time series observations from LEO-15 and MVCO. A publication describing the model and the data sets on which it is based is in review.

Application to Spatial Variability from Ivan: The ripple model was also used to examine ripple wavelength data from the RipplesDRI/SAX04 experiment. The ripple model was run with wave forcing from SWAN and WW3 nested model runs with varying wave energy dissipation rates in the SWAN shelf model. The grain size input into the ripple model was also varied to determine the sensitivity of the predicted wavelength to dissipation rate and grain size. It was found that the predicted wavelength is highly sensitive to grain size, but insensitive to dissipation rate (Figure 3). By minimizing the error between the observed and predicted wavelength the model was used to invert for grain size and was found to predict a depth distribution of grain sizes fairly similar to those measured during the experiment and historical values from that location (Figure 3). A publication describing the application of this model to the Hurricane Ivan/ SAX04 data set is in preparation.
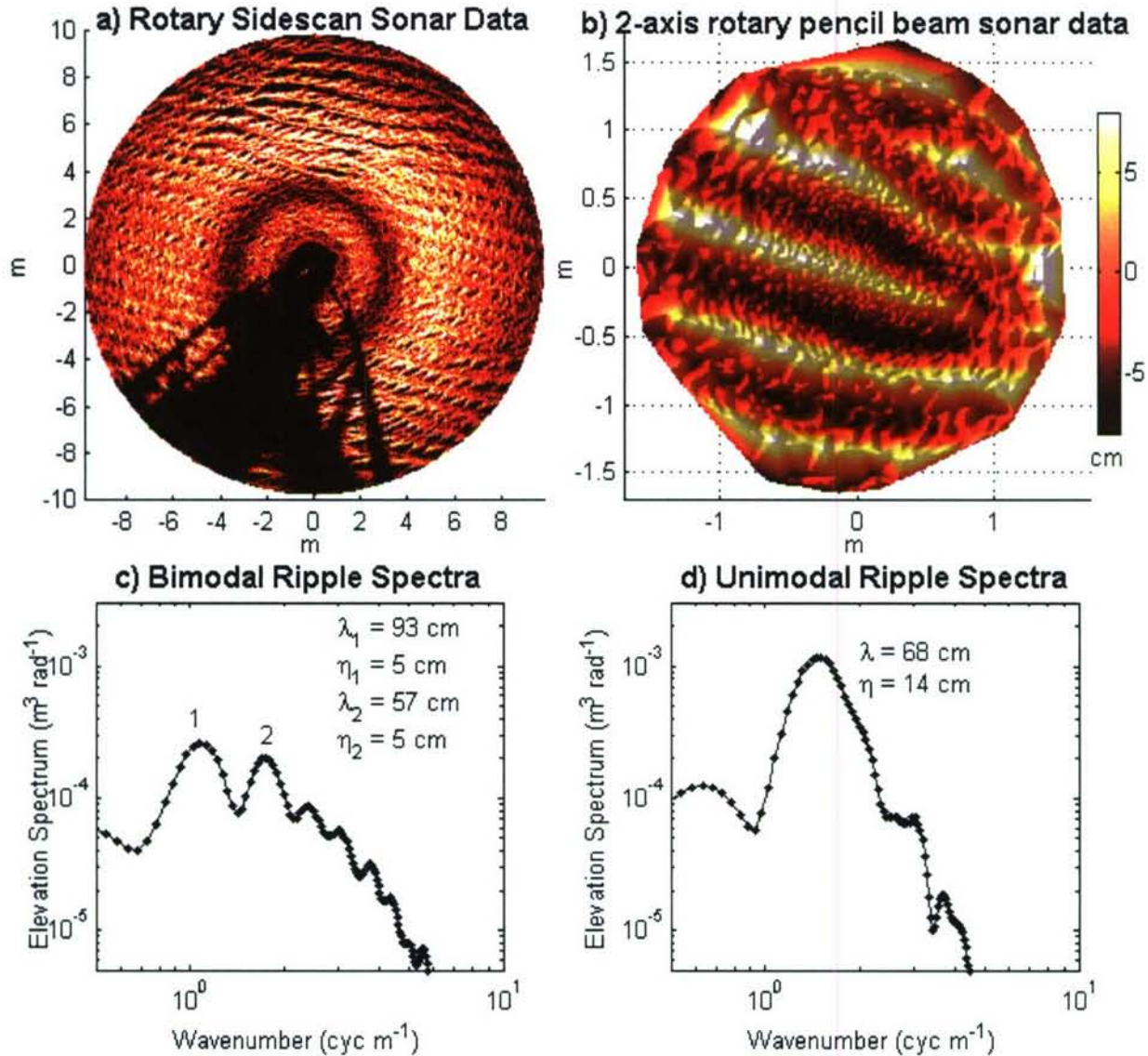
IMPACT/APPLICATIONS

The capability of Remus to quantify variations in bedform geometry has implications both for research and for naval operations. The system provides unprecedented combination of high resolution and large spatial coverage of seabed conditions that can be related to seabed mobility, potential for mine burial (Traykovski et al, 2005) and ability to acoustically detect mines. The temporal ripple model provides a useful tool for examining and predicting ripples that are not in equilibrium with forcing.

RELATED PROJECTS

This project is closely related to other RipplesDRI projects such as D. Hanes' efforts to map ripple geometry in relation to grain size on the Florida Shelf and T. Herbers' wave modeling results were used in the combined wave and ripple model. It also has relations to the mine burial prediction program in that variability in grain size and bedforms has first order implications regarding the predictability of mine burial. The modeling work was dependent on previous ripple geometry time series data sets, some of which were obtained under ONR funding.
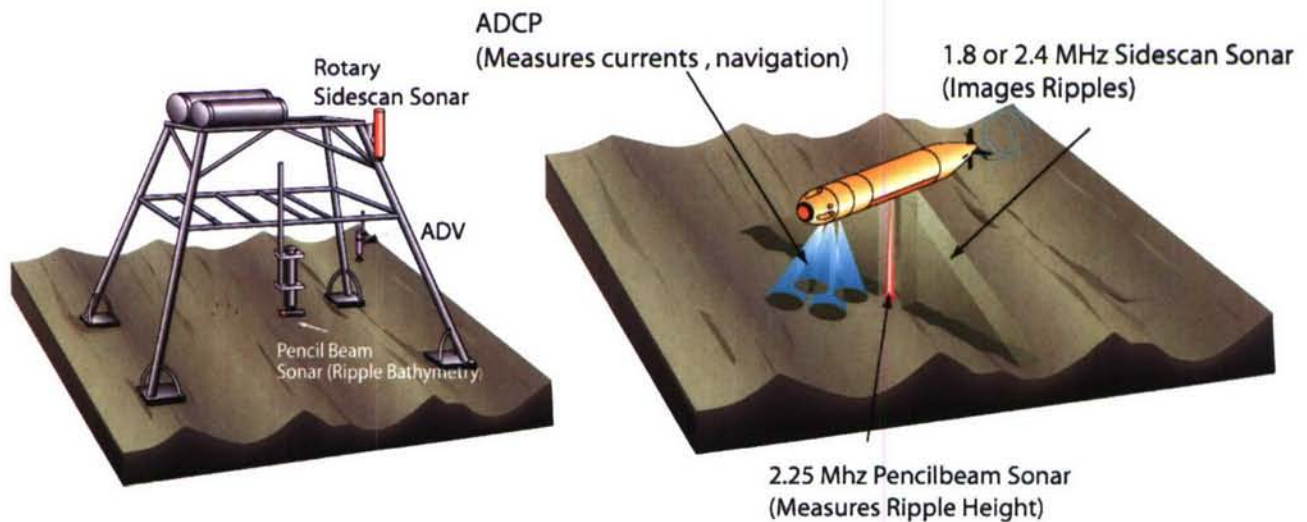
Figure 1. Left: A schematic diagram of a bottom mounted instrument frame to measure the temporal evolution of ripple parameters at a single location similar to those deployed al MVCO and LEO-15 . Instruments on the frame measures ripple geometry and hydrodynamic forcing. Right: An REMUS AUV was used to measure the spatial distribution of bedforms during two cruises at the Florida site. The AUV had a sidescan sonar that imaged ripple topography and a pencil beam echo sounder that measured ripple height.

a) Rotary Sidescan Sonar Data

b) 2-axis rotary pencil beam sonar data

c) Bimodal Ripple Spectra

$\lambda_1 = 93$ cm
$\eta_1 = 5$ cm
$\lambda_2 = 57$ cm
$\eta_2 = 5$ cm

d) Unimodal Ripple Spectra

$\lambda = 68$ cm
$\eta = 14$ cm

Figure 2. a and c) Rotary sidescan imagery of a bimodal ripple spectra taken at the beginning of the storm showing the long wavelength ripples (peak 1 in c) left from a previous event and new shorter wavelength ripples (peak 2 in c) that are being formed by waves with shorter orbital diameters. b and d) 2 axis rotary pencil beam sonar microtopography of a unimodal ripple spectra showing long wavelength ripples left after the end of a storm. Both spectra in c and d are calculated from 2-axis pencil beam data as it has elevation data.
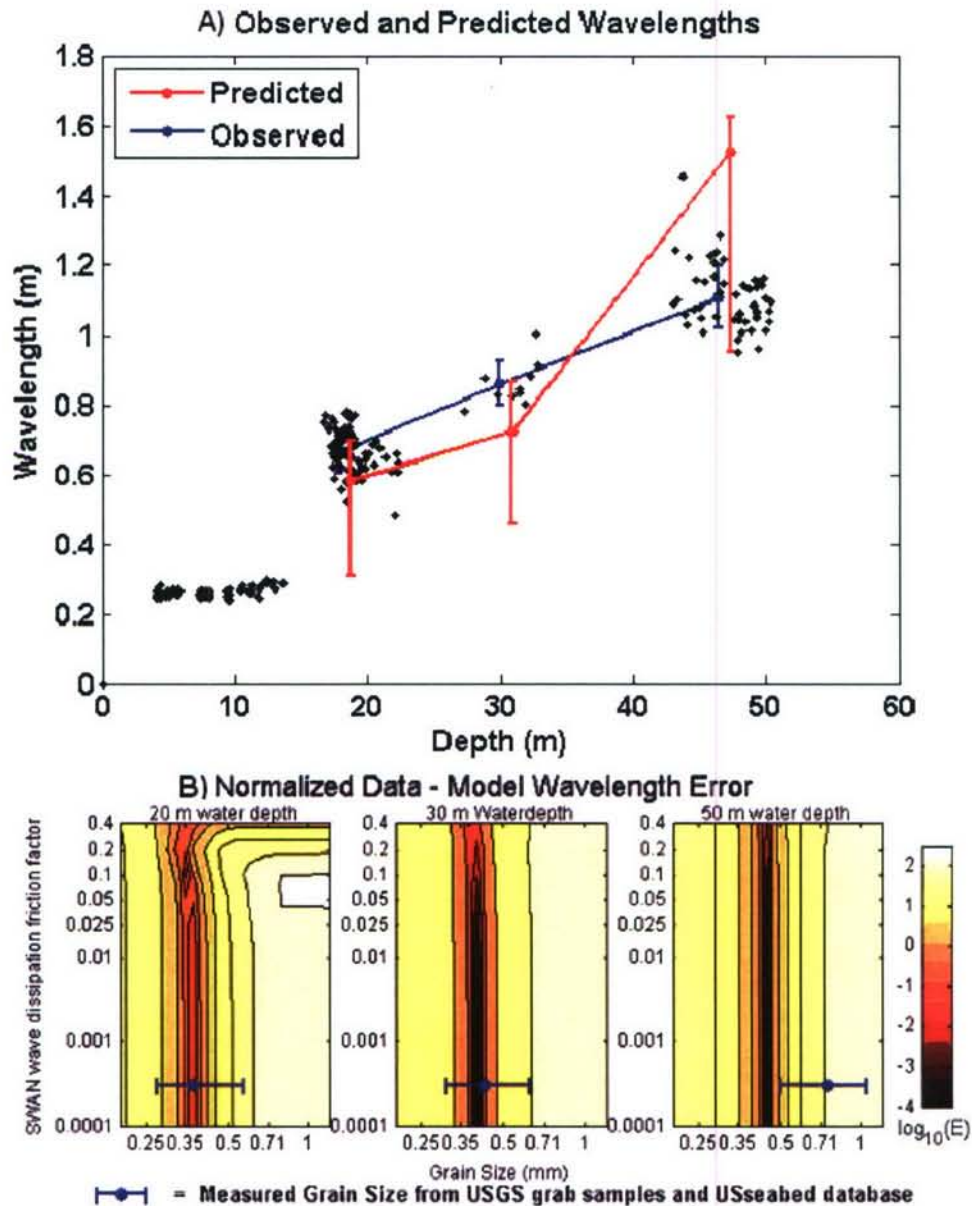
Figure 3. A) Predicted (red line) and observed (blue line and black dots) ripple wavelength based on the measured grain size from in-situ samples taken at the same time as the ripple measurements in 20 and 30 m water depths and a USGS historical data base (USseabed) in 50 m of water B) Colored contour plots show the difference between the combined wave and ripple model predictions and the observed relict ripple wavelengths from hurricane Ivan for depths of 20, 30 and 50m for varying grain size and wave friction factor inputs. The error is insensitive to dissipation, but very sensitive to grain size. The minimum errors are achieved at grain sizes fairly close the actual measured grain sizes.

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